Russian Wildrye Seedling Development under Three Temperature Regimes

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ABSTRACT

Poor seedling vigor of Russian wildrye [*Psathyrostachys juncea* (Fisch.) Nevski] has resulted in frequent establishment failures and deterred more widespread use of this grass. This study was conducted to ascertain coleoptile length and seedling emergence of Russian wildrye under three temperature regimes at a 70-mm planting depth in a Parshall fine-sandy loam soil (coarse-loamy, mixed, superactive, frigid Pachic Haplustolls; bulk density = 1.3 g cm^{-3}) and to compare seedling development of four tetraploid populations with two diploid check cultivars. Diurnal temperatures (12/12 h, both dark) were 7/10°C (low), 13/16°C (medium), and 19/22°C (high). Soil water was maintained near field capacity. Coleoptile lengths for the low-, medium-, and high-temperature treatments averaged 48.3, 50.2, and 55.5 mm, respectively. Low and sporadic seedling emergence of 'Vinall' at all temperature treatments resulted in a significant ($P \leq 0.01$) entry × temperature interaction. Entries had similar ranking for emergence within each temperature regime, and all entries but Vinall had increased emergence in response to increasing temperatures. Seedling emergence from a 70-mm planting depth was dependent on elongation of both the coleoptile and first seedling leaf, and diploid entries failed to emerge in most instances. Seedling emergence at the low-, medium-, and high-temperature treatments averaged 4.5, 14.5, and 16.5%, respectively, for the two diploid check cultivars and 16.5, 27.0, and 37.0%, respectively, for the four tetraploid populations. Tetraploids had greater seedling establishment potential than diploids, but any advantage for early-spring seeding would be due to factors other than soil temperature.

Russian wildrye is an introduced, cool-season bunchgrass that is used to supplement native rangeland in semiarid regions of North America (Rogler and Schaaf, 1963; Smoliak and Slen, 1975). It has an abundance of basal leaves that maintain relatively high levels of digestibility and protein with advancing maturity (Lawrence and Troelsen, 1964; Knipfel and Heinrichs, 1978). Thus, Russian wildrye pastures are often stockpiled for use in late-summer and fall when nutritional quality of most grass species is low.

Poor seedling vigor of Russian wildrye has resulted in frequent establishment failures and deterred more widespread use of this grass (Lawrence, 1963). Seedling vigor was an important selection criterion in the development of the diploid ($2n = 2x = 14$) cultivars Swift (Lawrence, 1979), Bozoisky-Select (Asay et al., 1985), and Mankota (Berdahl et al., 1992), but stand establishment capability of these cultivars is still inferior to tetraploid ($2n = 4x = 28$) crested wheatgrass [*Agropyron desertorum* (Fisch. ex Link) Schultes] (Jefferson, 1993). Induced tetraploids ($2n = 4x = 28$) of Russian wildrye have larger cell size (Berdahl and Barker, 1991) and more robust seedlings than their diploid counterparts (Lawrence et al., 1990; Berdahl and Barker, 1991; Jefferson, 1993; Jensen et al., 1998). An induced tetraploid cultivar with improved seedling vigor, Tetracan, has been licensed for sale in Canada (Lawrence et al., 1990).

Berdahl and Ries (1997) evaluated stand establishment of diploid and tetraploid Russian wildrye populations in the field and seedling development in a controlled-environment chamber. Tetraploids averaged 33% greater initial seedling emergence than diploids at both early- and late-field planting dates. In the controlled environment, diploid and tetraploid seedlings had greater coleoptile length and emergence percentage from a 63-mm planting depth at a 16/13°C diurnal temperature regime than at 23/18°C, both with a 14/10-h photoperiod at a light intensity of 900 mol m^{-2} s^{-1}, even though seedling growth rate was reduced at the lower temperatures. Other studies (Rosenquist and Gates, 1961; Ellern and Tadmor, 1966; McWilliam et al., 1970) have reported slower rates of germination and seedling development for grass species at reduced temperatures, but no other study has reported a positive relationship between size of grass seedling tissues and lower temperatures.

It may be possible to improve stand establishment of Russian wildrye by early spring seeding if lower temperatures result in increased size and greater emergence of young seedlings. Also, it would be helpful to know the affect of temperature on growth and development of young seedlings in efforts to select Russian wildrye germplasm for improved seedling vigor. The objective of this study was to ascertain coleoptile length and emergence of diploid and tetraploid Russian wildrye seedlings planted at a 70-mm depth in soil at three temperature regimes.

MATERIALS AND METHODS

Four tetraploid populations and two diploid check cultivars, Mankota (Berdahl et al., 1992) and Vinall (Hein, 1960), of Russian wildrye were included in this study. Mankota, was selected for greater coleoptile length and seedling emergence from deep planting (Berdahl et al., 1992), but none of the other entries had been previously selected for traits associated with seedling vigor. All seed was harvested from isolated field nurseries near Mandan, ND, in 1994 and stored at −20°C until Nov. 1999 when this study was initiated. Germination percentage was measured according to procedures of the Assoc. of Official Seed Analysts (1981), and seed mass was measured on four random samples of 200 seeds each for each entry (Table 1).

An experimental unit consisted of a plot of 50 seeds planted at a 70-mm depth in a 30-cm row with a 7-cm spacing between rows. The growth medium was Parshall fine-sandy loam soil that was packed uniformly over the seed to a bulk density of 1.3 g cm^{-3}. Trays measuring 21 by 31 by 9 cm accommodated

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Table 1. Germination percentage and seed mass of four tetraploid Russian wildrye populations and two diploid check cultivars harvested in 1994 near Mandan, ND.

Entry	Ploidy level	Germination	Seed mass
		%	mg seed^{-1}
R4X14-27	Tetraploid	93.5	5.1
R4X19-19	Tetraploid	91.5	5.2
R4X35-3	Tetraploid	95.5	4.9
R4X37-27	Tetraploid	93.0	5.3
Mankota	Diploid	92.5	2.9
Vinall	Diploid	95.0	2.7
SEM		1.1	0.1
LSD0.05		3.4	0.3

two plots each and were watered to field capacity (25% soil water by weight) immediately after planting. Net weight of each tray was measured every second day, and the soil was maintained near field capacity by sprinkling with tap water. Diurnal temperature treatments (12/12 h, both dark) of 7/10°C (low), 13/16°C (medium), and 19/22°C (high) were maintained at ±0.6°C in a seed germinator (Model SG-30, Hoffman Manufacturing Co., Albany, OR[1]). The three temperature treatments were run sequentially in the same germinator. A single run of the seed germinator at each of the three prescribed temperature regimes included four replicates of the four tetraploid Russian wildrye populations and two check cultivars in a randomized complete-block design (RCBD). The entire experiment was repeated to determine variability among runs and interaction effects involving runs. Soil was washed from the developing seedlings, and coleoptile lengths were measured as soon as seedling emergence was essentially completed at 38, 21, and 14 d after planting, respectively, for the low, medium, and high-temperature treatments. Only those seedlings with the first foliage leaf perforated through the coleoptile sheath were measured for coleoptile length. A final measurement of seedling emergence also was recorded on these dates.

Data were analyzed as a RCBD in a split-split plot arrangement with temperature treatments (whole plots), populations (subplots), and runs in a second split all considered as fixed effects (Steel and Torrie, 1980; SAS Institute, 1990). Subsequently, a separate ANOVA was calculated for each temperature treatment, and population means within each temperature were compared using an LSD test.

[1] Mention of a trademark or proprietary product in this paper does not constitute a guarantee or warranty of the product by the USDA or the Agricultural Research Service and does not imply its approval to the exclusion of other products that also may be suitable.

RESULTS AND DISCUSSION

Seedling emergence averaged across temperature regimes and entries was 22.7 and 21.9%, respectively, for Runs 1 and 2, a non-significant difference ($P \leq 0.11$). Emergence increased with increasing temperatures ($P \leq 0.01$) for all entries except Vinall. The low and sporadic emergence of Vinall at all three temperatures (Table 2) contributed to a significant ($P \leq 0.01$) entry × temperature interaction. The entry × temperature interaction was not significant ($P \leq 0.34$) when Vinall was not included in the ANOVA. The entry × run interaction for seedling emergence was significant ($P \leq 0.05$), primarily because all entries except Mankota had slightly greater emergence in Run 1 than Run 2. The entry × run interaction was not significant ($P \leq 0.48$) when Mankota was not included in the ANOVA. Entries had similar ranking for percentage emergence within each temperature regime, regardless of run. Coleoptile lengths averaged over temperature regimes and entries were 54.4 and 51.4 mm, respectively, for Runs 1 and 2, a significant difference ($P \leq 0.01$). Coleoptile length increased as temperature increased ($P \leq 0.01$) (Table 2), and the entry × temperature and entry × run interactions for coleoptile length were not significant at $P \leq 0.18$ and $P \leq 0.25$, respectively.

The consistent increase in coleoptile length with increasing temperatures does not agree with results from a previous study (Berdahl and Ries, 1997) where coleoptile length of Russian wildrye seedlings was greater at a 16/13°C diurnal temperature regime than at 23/18°C, especially for tetraploid populations. The previous study was maintained at approximately 50% available soil water by volume, and all treatments were subjected to a 14-h photoperiod. Seedlings may have been subjected to drying in the previous study, especially at the high-temperature treatment. In the field, seedling emergence of these same Russian wildrye populations was more rapid and greater in late-May and early-June plantings than in late-April and early-May plantings (Berdahl and Ries, 1997). During a 7-yr period at Mandan, ND, soil temperatures at a 5-cm depth averaged 6.3 and 8.2°C at 0830 and 1500 h, respectively, during the first week in May and 13.4 and 15.6°C, respectively, at these hours during the first week in June. Diurnal temperatures of 20/30°C (dark/light) are prescribed by the Assoc. of

Table 2. Seedling emergence and coleoptile length of four tetraploid Russian wildrye populations and two diploid check cultivars planted at a 70-mm depth in soil and maintained at three temperature regimes.

Entry	Ploidy level	Emergence				Coleoptile length			
		7/10°C	13/16°C	19/22°C	Mean	7/10°C	13/16°C	19/22°C	Mean
		%				mm			
R4X14-27	Tetraploid	23	33	43	33.3	53	52	60	55.2
R4X19-19	Tetraploid	10	20	26	19.0	46	49	54	49.4
R4X35-3	Tetraploid	7	15	31	17.9	46	50	54	49.9
R4X37-27	Tetraploid	25	40	48	37.6	52	54	59	55.1
Mankota	Diploid	8	24	29	20.6	51	54	58	54.6
Vinall	Diploid	1	5	4	3.2	42	42	48	44.0
SEM		1.4	1.8	3.2	2.3	0.5	0.9	0.8	0.7
LSD 0.05		4.4	5.6	9.5	6.5	1.5	2.6	2.4	2.1
Tetraploid mean		16.5	27.0	37.0		49.3	51.3	56.8	
Diploid mean		4.5	14.5	16.5		46.5	48.0	53.0	

Official Seed Analysts (1981) for germination tests of Russian wildrye. This suggests that the high-temperature treatment (19/22°C) used in the present study, which corresponds to near-maximum soil temperatures at a 5-cm depth in July and August at Mandan, should not be high enough to inhibit plant cell division and growth, provided that water is adequate.

In the present study, tetraploid populations R4X14-27 and R4X37-27 ranked highest for both emergence percentage and coleoptile length, and the diploid check cultivar Vinall ranked last for all temperature treatments (Table 2). Coleoptile length of the diploid Mankota check was similar to coleoptile length of the highest ranking tetraploid populations, R4X14-27 and R4X37-27, at all three temperature regimes. This relationship was not found for seedling emergence where Mankota was significantly ($P \leq 0.05$) lower than the two highest ranking tetraploid populations at each temperature. None of the populations had an average coleoptile length that exceeded 70 mm, which would be needed to penetrate the soil surface from a planting depth of 70 mm. Emergence was dependent on elongation of the coleoptile and the first seedling leaf. The high emergence percentage of tetraploid populations R4X14-27 and R4X37-27 could be attributed to both coleoptile length and a robust first seedling leaf, whereas the first seedling leaf of the two diploid populations was not able to penetrate the soil surface in most instances. Low temperature reduced the emergence of both diploid and tetraploid entries proportionally more than it reduced coleoptile length. This suggests that low temperature reduced the capacity of the first seedling leaf to grow through the final 10 to 20 mm of soil. Mesocotyls of the diploid and tetraploid seedlings were not elongated, in contrast to a report by Rogler (1954) that a small percentage of crested wheatgrass seedlings developed an elongated mesocotyl when seeded at a 76-mm depth. For Russian wildrye in the present study, total seedling emergence from deep planting provided a more integrated measure of overall seedling vigor than coleoptile length per se and was easier to measure. Coefficients of variation ranged from 22.6 to 32.3% for emergence at the three temperature regimes and from 3.0 to 4.9% for coleoptlile length. Thus, additional replication may be needed when seedling emergence rather than coleoptile length is used as a selection criterion to improve stand establishment potential. Differences in rate of emergence may also provide an important measure of seedling vigor, as suggested by Asay and Johnson (1980).

CONCLUSIONS

Soil water was maintained near field capacity in the present study, and a consistent increase in coleoptile length and seedling emergence was found as temperature increased (Table 2). In a previous study (Berdahl and Ries, 1997), coleoptile length and seedling emergence were greater at 16/13°C diurnal temperatures than at 23/18C, but seedlings may have been subjected to drought stress, especially at the high temperature treatment. On the basis of results of the present study, we conclude that any advantage for early compared with later spring seeding under field conditions would be due primarily to factors other than low soil temperature. Soil at the recommended seeding depth of 12 to 20 mm for Russian wildrye (Rogler and Schaaf, 1963) is subject to drying; thus, early spring seedings with lower air temperatures are less subject to soil drying than later seedings. Regardless of seeding date, establishment success of Russian wildrye would be improved if germplasm were available that could emerge from greater soil depths where fluctuations in soil water would not be as large. Tetraploid germplasm in the present study had no previous selection for coleoptile length or seedling emergence from deep planting; yet two of the four tetraploid populations had similar coleoptile length and greater seedling emergence than Mankota (Table 2), a diploid check cultivar that had undergone intense selection for coleoptile length and seedling emergence from deep planting (Berdahl et al., 1992). We conclude from these results and results of other studies (Lawrence et al., 1990; Berdahl and Barker, 1991; Jefferson, 1993; Jensen et al., 1998) that tetraploid seedlings are more robust and have improved establishment potential compared with diploids. The high temperature treatment of the present study (19/22°C) and a planting depth of 70 mm in soil would be appropriate for screening Russian wildrye germplasm for increased coleoptile length and seedling establishment potential. This treatment allowed adequate expression of coleoptile length and seedling emergence, and evaluations at 19/22°C required less time than the low- and medium-temperature treatments.

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